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INTERCEPTOR DEVELOPMENT ENGINEERING COST RESEARCH

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Development Engineering cost was hypothesized to be a function of the complexity of the item being developed and the time it takes to develop it. The hypothesis is further refined by stating that the cost of development is related to the monthly expenditure rate (size of the design staff) and duration. Further, the monthly expenditure rate is different at different phases of the development program and peaks in the period prior to Critical Design Review (CDR). It is further hypothesized that the expenditure rate in other periods is related to the peak in a predictable manner and that the peak expenditure rate is related to technical and programmatic complexity.

When the research effort was completed, it resulted in a recommended CER which relates Development Engineering cost to complexity and Duration by program phase. The use of Durations by milestone as independent variables may advance the state-of-the-art in cost analysis.

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INTERCEPTOR DEVELOPMENT
ENGINEERING COST RESEARCH

Jeff A. McDowell

FEBRUARY 1993

Prepared for

THE TWENTY-SEVENTH ANNUAL
DOD COST ANALYSIS SYMPOSIUM

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TABLE OF CONTENTS

SECTION		PAGE
1	INTRODUCTION	1
2	OBJECTIVES	2
3	RESEARCH	3
	3.1 HYPOTHESIS	3
	3.2 DATA COLLECTION	6
	3.3 NORMALIZATION	6
	3.4 DATABASE	7
	3.5 SCHEDULE COMPONENT DEVELOPMENT	9
	3.6 TECHNICAL COMPONENT DEVELOPMENT	12
	3.7 COMBINED EQUATIONS	13
4	EXTENSIONS AND ALTERNATIVES	16
5	CONCLUSIONS	21
	5.1 RESULTS	21

TABLES		PAGE
3-1	Peak Equations Evaluated	12
4-1	Equations with Adjustments Evaluated	20

FIGURES		PAGE
3-1	Hypothesis	5
3-2	Sample Data Point	8
3-3	Sample Expenditures by Period	9
3-4	Values for a_i	11
3-5	Peak Equation	14
3-6	Combined Equations	15
4-1	Adjustment Issue Quantification	19
4-2	Peak Equation Comparison	20

1
INTRODUCTION

This Paper contains excerpts from "Interceptor Development Engineering Cost Research", CR-0616, Tecolote Research, Inc., February 1993. Proprietary Data has been removed so that it could be presented at the DoD Cost Analysis Symposium. This paper presents the techniques utilized in this cost research effort and its results.

2
OBJECTIVES

The objective of this effort was to examine Development Engineering of Missile Air Vehicles through review of existing estimating methodologies and data research, collection, normalization, and development of recommended methods/CERs for use in USASSDC estimates. Development Engineering is typically a significant cost driver of the R&D phase. In fact, the Development Engineering cell alone may constitute as much as one-third of the R&D phase costs. Development Engineering may sometimes be the largest cost element in R&D. Given the magnitude of Development Engineering, the development of appropriate estimating techniques for DE is of proper concern.

The definitions of Development Engineering is consistent in cost estimating guidance. The DA PAM 11-2 Research and Development Cost Guide for Material Systems, the DCA-P-92(R) Instructions for Reformatting the BCE/ICE, and the new Cost Analysis Manual define Development Engineering essentially the same. The latest definition is:

> "This element includes the costs of study, analysis, design development, evaluation, testing, and redesign for the system component(s) during the system development efforts. It includes the design efforts of preparing specifications, engineering drawings, parts lists, wiring diagrams, test planning and scheduling, analysis of test results, data reduction, report preparations and establishment of reliability, maintainability, and quality assurance control requirements. It also includes the costs of raw and semi-fabricated material plus purchased parts consumed in the performance of component engineering efforts. Also included is engineering test equipment such as oscilloscopes, transducers, recorders, radio transmitters, converters, discriminators, receivers, and other equipment required to accomplish the engineering function for the specified system components. This element also includes the engineering efforts in support of pre-planned product improvements. Excluded from this element are the engineering efforts (producibility engineering and planning) to ensure producibility of the item or system prior to quantity procurement."

3
RESEARCH

After reviewing existing Development Engineering CERs and studying the estimating challenges of this element, it is apparent that schedule must play an important role in the cost of air vehicle development.

Development Engineering cost is hypothesized to be a function of the complexity of the item being developed and the time it takes to develop it. The complexity of the item may be a function of technical parameters which may be represented by unit cost. which in turn, may be used as a surrogate of complexity. Many existing Development Engineering CERs used some variation of prototype cost and that is a value that is readily available to the estimator. Other complexity variables may be the leverage a program receives from previous or parallel programs or programmatic complexities such as the number of major subcontractors, etc.

Development Engineering cost is also hypothesized to be a function of schedule. The total duration of the development program is a compelling cost driver: some minimum cadre of designers should be expected to be applied for the duration of the development contract. However the size of this staff may in fact vary over time especially as issues are resolved during the test program and as the design becomes more stable.

3.1 HYPOTHESIS

The hypothesis developed for this study is that Development Engineering cost may be represented in two parts. The first being a technical component. The technical component is hypothesized as an equation that will compute the average size of the staff (or monthly expenditure rate) that it takes to accomplish the basic design of the air vehicle. This equation will have independent variables such as hardware unit cost or physical parameters. It may also have variables that allow the addressing of program leverage or the programmatic complexity. The second part is the schedule component. This is hypothesized as being a series of terms where a portion of the technical component is applied to periods of time between milestones. The product of these components results in total Development Engineering costs.

The hypothesis is further refined by stating that the cost of development is related to the monthly expenditure rate (which is, in turn related to the size of the design staff) and duration. Further, the monthly expenditure rate is different at different phases of the development program and peaks in the period prior to Critical Design Review (CDR). It is further hypothesized that the expenditure rate in other periods is related to the peak in a predictable manner and that the peak expenditure rate is related to technical and programmatic complexity.

Summarizing the hypothesis algebraically, Development Engineering is related to expenditure rate and duration,

$$DE\$ = f(rate, duration),$$

and that the peak monthly expenditure rate, R_{max} is related to air vehicle complexity,

$$R_{max} = f(complexity),$$

and that the expenditure rate during each period i may be expressed as

$$R_i = a_i * R_{max}.$$

Now if observed data can be utilized to determine a set of coefficient a_i and an equation to predict R_{max} can be determined, then the cost of Development Engineering may be expressed as

$$DE\$ = \sum a_i * R_{max} * D_i$$

or

$$DE\$ = \sum R_i D_i$$

where D_i is the duration of each period. This is illustrated graphically in Figure 3-1.

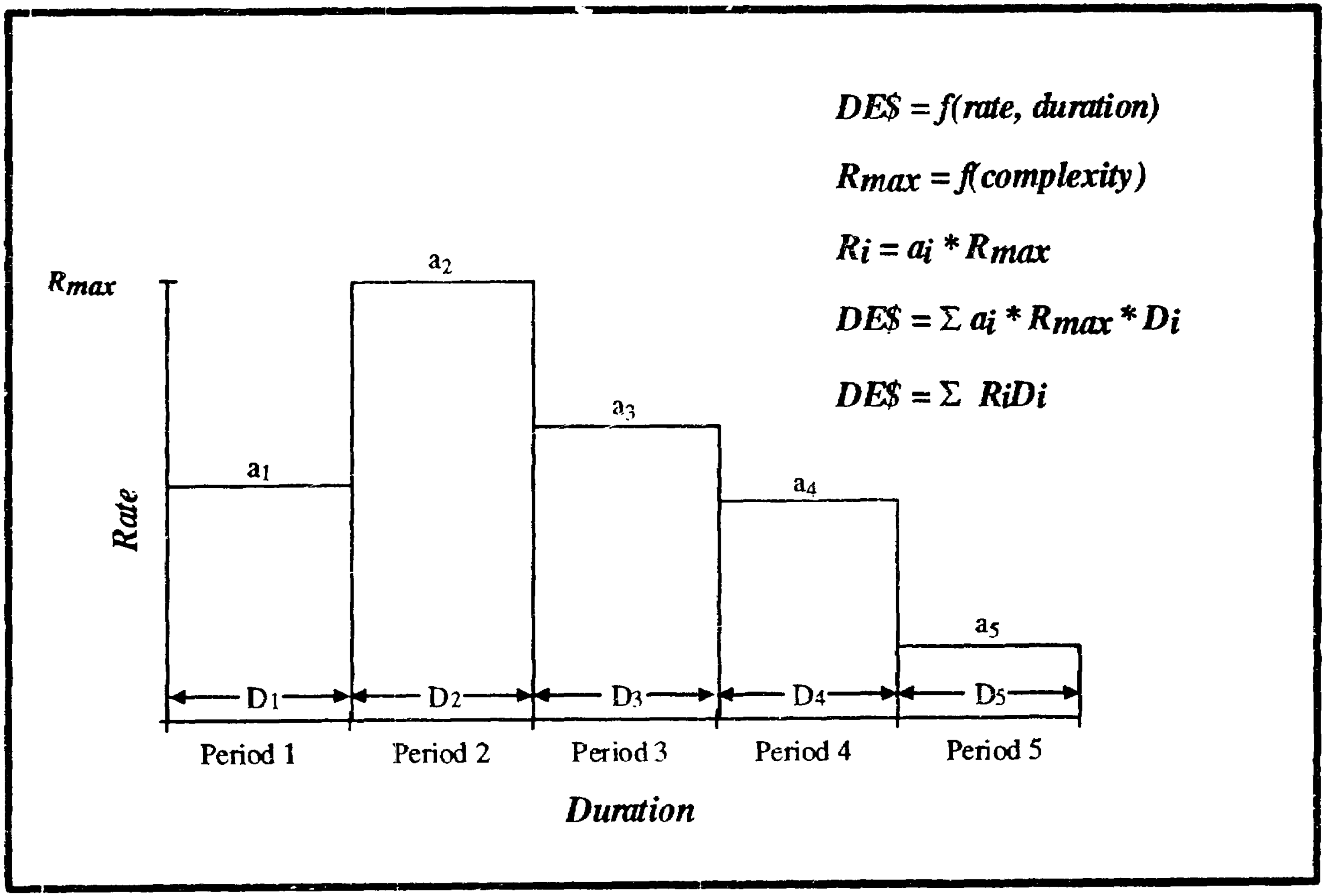

Figure 3-1
Hypothesis

The bulk of the task centered around two efforts. First to determine the set of coefficients a_i and second to determine the equation for R_{max}.

3.2 DATA COLLECTION

Data was sought for missile system air vehicle development contracts for all phases: Engineering and Manufacturing Development (EMD), Demonstration and Validation (D&V), Product Improvement Programs (PIP), and experiments. In particular, recent USASSDC experiments and USASSDC Demonstration and Validation (D&V) programs cost data was sought. The most desirable data was monthly cost reports. Contractor Cost Data Reports (CCDRs) were preferred over Cost Performance Reports (CPRs) because the non-recurring engineering was visible. Monthly data for fifteen (15) systems were successfully obtained. For twenty-two (22) systems, the final (or latest) available cost report was used. An additional nineteen (19) data points were used from prior studies. Source cost reports were not available for this last group though through conversation with those investigators the author has confidence that those data points were normalized correctly. The sources are summarized as:

Monthly CPRs	9
Monthly CCDRs	6
Single CPRs	10
Single CCDR	9
CEAC Infoarch	6
Prior Study	13
Other	2

3.3 NORMALIZATION

Normalization of the data was done in two steps. First, the effects of inflation were removed using the DoD indices contained in the 19 May 92 inflation letter to express the values in FY88 dollars. Second, Development Engineering cost was isolated. As stated above, the CCDRs did not require mapping. In using CCDR data, the non-recurring engineering was equated with Development Engineering. In the CPRs, many systems had separate line items for prototype fabrication and for design. Design was equated with Development Engineering. However some system's CPRs contained accounts for Prime Mission Equipment (PME) that was comprised of Development Engineering and Prototype

Manufacturing together. For these systems, Development Engineering was isolated by taking manufacturing cost found on the functional page and subtracting that value from the PME cost and equating the balance with Development Engineering. For obtaining normalized hardware unit costs, learning curves for production units are assumed at 90%, EMD units at 95%, and D&V units at 100%. EMD to production step function is assumed at 1.66. All costs contained in this paper (unless otherwise noted) are in millions of FY88 dollars and include G&A and fee. Each r^2 that is presented in this paper is adjusted for degrees of freedom and each Standard Error (SE) is in unit space.

3.4 DATABASE

The database for evaluating the hypothesis is exemplified in the sample data point shown in Figure 3-2. Each parameter in Figure 3-2 is defined as follows.

Development Engineering cost is as defined in DA PAM 11-2, P-92, and the Cost Analysis Guide. This is contract cost for subcontractors as well as prime; Government cost is excluded. Where possible, software costs are excluded. Prototype Manufacturing is also as defined by DA PAM 11-2, P-92, and the Cost Analysis Guide. The cost of first prototype is the theoretical cost of the first prototype assuming slopes as defined above by program phase.

Design Basis is a new term introduced for this study. It is the Development Engineering cost incurred in the period from Preliminary Design Review (PDR) to CDR. That is, the amount of effort to actually accomplish the air vehicle design. Peak design effort is the average monthly expenditure rate observed during this period. Prototype Quantity is the number of Air Vehicles assembled during the contract. Test quantity is the number of Air Vehicles flown. Sled tests and chamber tests are not included. The R&D Slope Basis is the cumulative average learning curve slope percentage used for each data point which varies by program phase. The Duration is the number of months from contract award to contract end. Missile Weight is expressed in pounds and is the launch weight for the entire Air Vehicle. The Software Cost shown in the final column are those costs that were specifically available on the cost report and could be confidently associated with the Air Vehicle.

Figure 3-3 presents an example regarding the expenditures during specified periods of time. For each system, three rows of values are shown. The first row is the number of months per period, the second is the total cost reported for that period, and the third is the observed average cost per month during that period.

PARAMETER	VALUE
SOURCE	CPR
DEVELOPMENT ENGINEERING (FY88M$)	169.841
PROTOTYPE MANUFACTURING (FY88M$)	146.484
PEAK (FY88M$)	4.257
DESIGN BASIS (FY88M$)	63.857
PROTOTYPE QUANTITY	34
TEST QUANTITY	28
PROTOTYPE CFU (FY88M$)	5.593
R&D SLOPE BASIS	0.95
PHASE	EMD
TOTAL DURATION (MO)	67
MISSILE WEIGHT (LBS.)	16400
CONTRACT AWARD	Feb-79
PDR	Jan-80
CDR	Apr-81
FIRST PROTOTYPE	Dec-81
FIRST TEST	Apr-82
LAST TEST	Aug-83
FOLLOW-ON	Jun-82
CONTRACT END	Sep-84

Figure 3-2
Sample Data Point

3.5 SCHEDULE COMPONENT DEVELOPMENT

Actual milestone dates were collected for the systems under study in order to determine the expenditure rate by period from the monthly data. These dates were obtained from project offices, Selected Acquisition Reports (SARs), fact books, prior studies, CPR variance notes, and public literature. Some actual milestone dates were missing. While the focus of this task is not to develop schedule estimating relationships, it was necessary to estimate missing milestones. This was accomplished by computing each milestone's median

	Award to PDR	**PDR to CDR**	**CDR to 1st Flight**	**1st Flight to Last**	**Last Flight to End**
Sample System					
Months	12	15	12	16	13
Period Cost	26747	63857	34805	37020	7965
Cost Per Month	2229	4257	2900	2314	613

Figure 3-3
Sample Expenditures by Period

percentage of the total duration. These median percentages were applied to each system, and from the total duration of each, the missing dates were computed. The observed median percentages are:

Contract award to PDR	0.14
PDR to CDR	0.26
CDR to 1st Flight	0.16
1st Flight to Last Flight	0.24
Last Flight to Contract End	0.20

The dates are the milestones at which certain events took place. The dates that were of interest to this study were those that should signal a change in the scope of the Development Engineering effort. Contract award is simply the beginning of the design effort.

Some staff is brought together to begin design of the system and mature it sufficiently for a PDR to take place. PDRs are conducted after top level design efforts are completed, but prior to the start of detailed design. A completed PDR represents approval to begin detailed design and the Development Engineering effort begins in earnest.

The heaviest design phase culminates in the CDR. CDR is conducted before release of design for fabrication. This signals completion of the bulk of the new design effort and is sometimes defined as drawings being 90% complete.

After CDR it would be expected that the size of the design staff would begin to decline. The next period would end with the delivery of the first air vehicle to the launch site for government acceptance. During this period the Development Engineering effort continues in support of the fabrication of the prototype. Upon completion of one prototype it could be expected that many design issues have been resolved and that a further decrease in the design staff would be forthcoming. Note that only Development Engineering is being addressed; the same engineers may take on more systems engineering or test engineering functions such that the total engineering staff assigned to a given contract may perform different tasks. The next milestone is the date of the first flight test. Upon success of the first flight it could be expected that more design issues have been addressed and that the design effort should decrease. From the data set it was observed that many systems held CDR after the test program began. The last test is the last flight of prototype hardware accomplished during the contract. At this milestone the majority of the design issues have been resolved and the Development Engineering effort should reach a minimum from this point until the end of the contract. An additional milestone of note is the beginning of a follow-on contract. For D&V this would be the beginning of the EMD contract; for EMD it would be the production contract. It was initially postulated that the beginning of a follow-on would coincide with a reduction in staff. While this may be true at an aggregate level, this was not observed for Development Engineering.

The spending rate per period of time was computed for each system and the ratio of each period's rate to the PDR-to-CDR period was computed to obtain the hypothesis coefficients, a_i. The median values by program phase were chosen as the preferred coefficients. The resulting values are shown graphically in Figure 3-4. In both of these figures, two sequences of milestones are shown. The first set is for those situations where

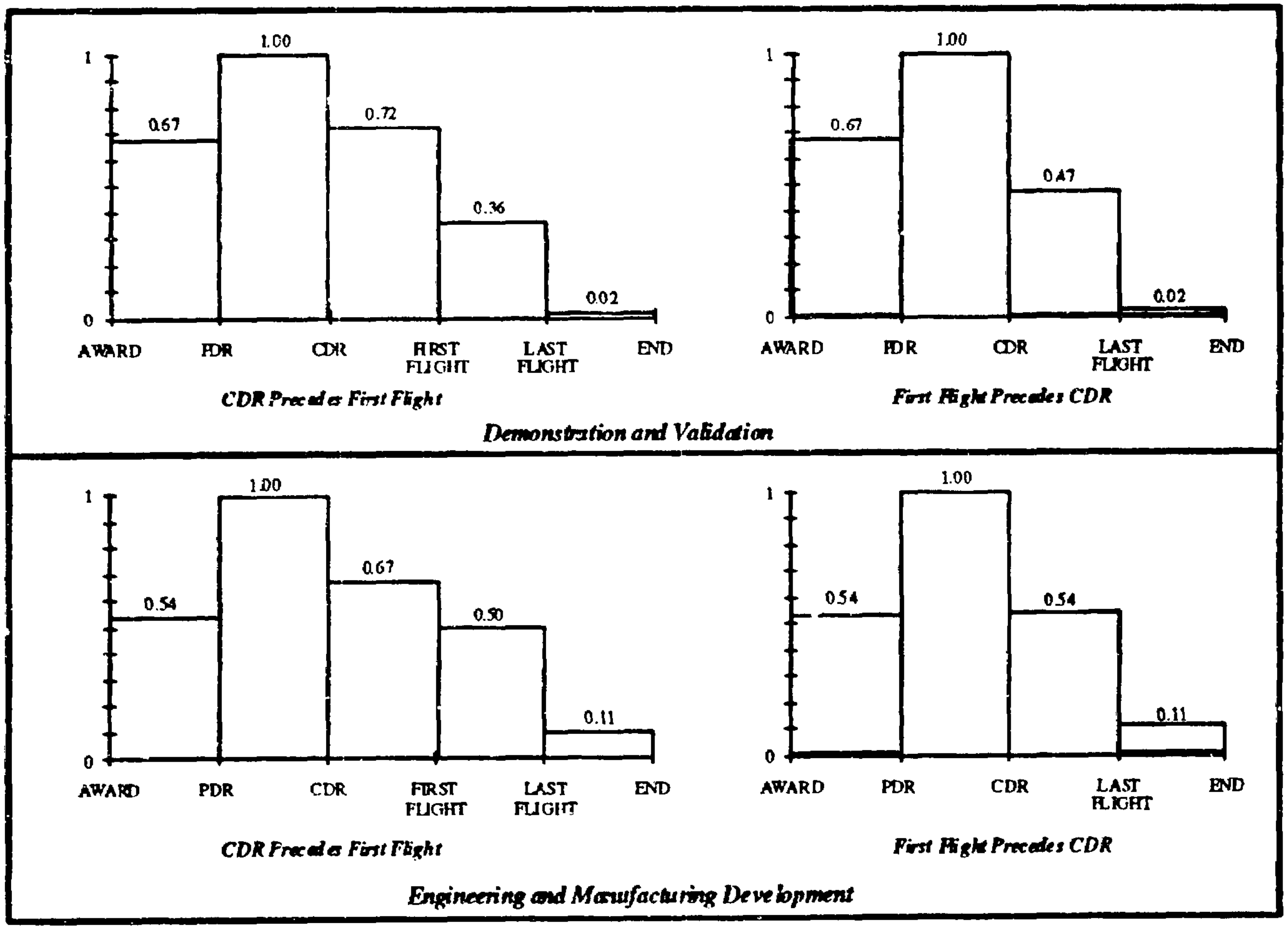

Figure 3-4
Values for a_i

CDR preceded the first flight. The second set is for those situations where first flight preceded CDR.

3.6 TECHNICAL COMPONENT DEVELOPMENT

For use in this portion of the hypothesized methodology, estimating relationships were explored that would compute the design basis cost or the peak design effort. Note that the peak design effort according to our working definition is the "PDR-to-CDR" cost-per-month. The database from was put into a statistics package, CO$TAT, and regressions were run. The dependent variables examined were Development Engineering Peak, Design Basis, and Development Engineering. The better predictive relationships were indeed those for Development Engineering Peak, R_{max}, which led to increased confidence in our hypothesis.

Table 3-1 presents the equations evaluated which estimate the peak expenditure rate of Development Engineering cost in millions of FY88 dollars. Parameters evaluated include the cost of prototype manufacturing (PM), duration in months (TD), missile weight in pounds (MW), prototype quantity (PQ), program phase dummy (D1 and D2), cost of first prototype (PCFU), mission type dummy (M1, M2, and M3), and an air vehicle completeness dummy (C2 and C3). The program phase stratification was by D&V (0,0), EMD (1,0), and PIP (0,1). The mission type was by surface-to-air (1,0,0), air-to-air (0,1,0), other tactical (0,0,1), or strategic/cruise (0,0,0). The Air Vehicle completeness stratification was by entire air vehicle (0,0), guidance section (1,0), and other section (0,1).

Table 3-1

Peak Equations Evaluated

#	EQUATION	r^2	SE	n	F	COMMENTS
1	$0.1656\,(PM^{0.5375})$	42	2.25	15	11	All data points.
2	$-0.3038+(0.0386\,PM)$	93	0.73	15	186	All data points.
3	$0.9693\,(PCFU^{0.4931})$	47	2.69	15	13	All data points.
4	$1.1129\,(PCFU^{0.5133})\,(MW^{-0.0212})$	43	2.79	15	6	All data points.
5	$0.6125\,(PCFU^{0.5433})\,(3.2529^{D1})\,(0.9194^{D2})$	72	2.29	15	13	All data points.
6	$0.6286(PCFU^{0.5171})\,(3.1495^{D1})$	64	3	12	11	Equation 5 less PIP programs.
7	$0.7935\,(PCFU^{0.5185})\,(1.9831^{D1})\,(0.6906^{D2})$	91	0.3	13	41	Equation 6 less two outliers.

Equations 1 through 6 are against the entire data set. Equation 2 has a good fit but the negative intercept may make it not useful for lower cost systems. Also, the use of *total* prototype manufacturing is not quite as satisfying as using the cost of one prototype in predicting the *peak*. Introducing missile weight as a further explainer of missile complexity (Equation 4) did not help nor did stratifying by mission type (Equation 5). However since there were only three points in the PIP category and these exhibited scatter, we removed these in Equation 6. Removing two outliers in Equation 7 provided for a good fit. We feel justified removing these two particular points as one had a well-publicized overrun which was not reflected on the cost reports and the second program has been redirected often. Equation 7 is the recommended equation. This is shown graphically in Figure 3-5.

3.7 COMBINED EQUATIONS

Combining the peak equation from Section 3.6 (R_{max}) with the schedule coefficients of Section 3.5 (a_i) lead to the recommended method shown in Figure 3-6. Six equations are presented which represent three program phases and two sequences of milestones.

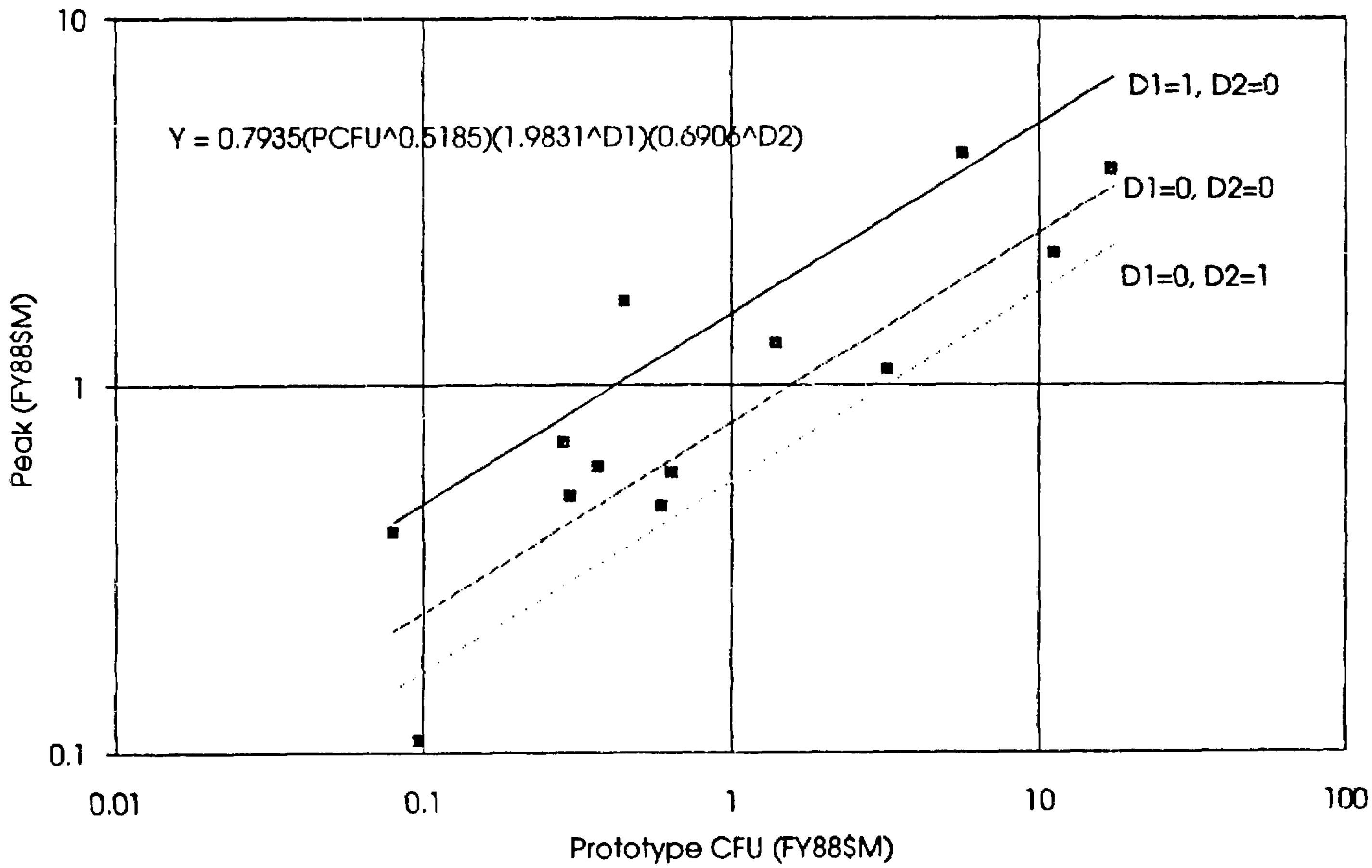
10
1
0.1
Peak (FY88$M)
0.01
0.1
1
10
100
Prototype CFU (FY88$M)
Y = 0.7935(PCFU^0.5185)(1.9831^D1)(0.6906^D2)
D1=1, D2=0
D1=0, D2=0
D1=0, D2=1

Figure 3-5

$$DE_{DemVal} = (0.67D_1 + 1D_2 + 0.72D_3 + 0.36D_4 + 0.02D_5)\ (0.7935\ PCFU^{0.5185})$$
$$DE_{EMD} = (0.54D_1 + 1D_2 + 0.67D_3 + 0.50D_4 + 0.11D_5)\ (1.574PCFU^{0.5185})$$
$$DE_{PIP} = (0.67D_1 + 1D_2 + 0.72D_3 + 0.36D_4 + 0.02D_5)\ (0.5480PCFU^{0.5185})$$

where:

DE_{DemVal} = D&V Development Engineering in Millions of FY88 Dollars
DE_{EMD} = EMD Development Engineering in Millions of FY88 Dollars
DE_{PIP} = PIP Development Engineering in Millions of FY88 Dollars
D_1 = Months from Contract Award to PDR
D_2 = Months from PDR to CDR
D_3 = Months from CDR to First Flight
D_4 = Months from First Flight to Last Flight
D_5 = Months from Last Flight to Contract End
PCFU = Prototype Cost of First Unit in Millions of FY88 Dollars

Alternatives where First Flight precedes CDR

$$DE_{DemVal} = (0.67D_1 + 1D_2 + 0.47D_3 + 0.02D_4)\ (0.7935\ PCFU^{0.5185})$$
$$DE_{EMD} = (0.54D_1 + 1D_2 + 0.54D_3 + 0.11D_4)\ (1.574\ PCFU^{0.5185})$$
$$DE_{PIP} = (0.67D_1 + 1D_2 + 0.47D_3 + 0.02D_4)\ (0.5480\ PCFU^{0.5185})$$

where:

D_3 = Months from CDR to Last Flight
D_4 = Months from Last Flight to Contract End

Figure 3-6
Combined Equations

4
EXTENSIONS AND ALTERNATIVES

Many estimating situations require that the estimator make further adjustments to a CER due to cost influencing issues that are not addressed by the CER's independent variables. These issues are usually unique and require subjective adjustments be made to a CER. The Development Engineering CER presented in Section 3 is particularly versatile and may be readily adapted to the use of such adjustments. This section discusses some variations and alternative uses of this paper's equations and data.

4.1 ADJUSTMENTS TO TERMS

The recommended equations from Section 3 are comprised of two components which may be separately tweaked or utilized independently. Consider some alternative ways to use the schedule component. First, the coefficients on the months for the duration terms may be adjusted. One example of doing this would be to examine the values in the database and select an analogous system's coefficients. Another example may be to subjectively adjust any single period as deemed appropriate. For example, if a program is expected to compete two contractors early in a development program and down select at PDR, then multiplying the "award to PDR" term by a value of two would be an appropriate adjustment. Another adjustment to the schedule component is if a system's design will be relatively stable at some point in time other than CDR, then that date may be used in lieu of the actual CDR date.

Now consider some alternative ways to use the peak component of Section 3.7's equations. In lieu of computing the peak expenditure rate from the CER, the peak term may be obtained by selecting analogous system values. The user may wish to obtain the peak value by entirely different means. This may be via a build-up of personnel required to design the system or by scaling from one of the values from the database. Also, for an on-going contract, an estimate at completion may be obtained from this method by extrapolating from an early month's actual expenditure rate.

4.2 ADJUSTMENTS PARAMETER

Another subjective issue that relates to estimating Development Engineering is design complexity, design heritage and programmatics. In the recommended methodology of Section

3-7, these issues are indirectly addressed as they already influence the value of the independent parameter, the prototype cost. Even so, the final effort in this study was to determine if our predictive ability could be improved using subjective adjustments to account for these issues. The adjustment parameter was hypothesized to be a measure of design challenge and programmatic complexity. The adjustment variable will be the product of two variables. One for complexity and one for programmatics. The value of each would vary about unity such that the nominal case would be equal to one and, therefore, have no effect on the total cost. These are computed based upon analyst judgment on several distinct issues.

Several design complexity issues were identified that were believed would further explain variation in the data. The first issue, design *challenge* is the analyst's opinion of the complexities involved in the design of an item based upon technology, tolerances, parts count, etc. The *packaging* issue is to account for systems where space is a premium and that extensive design effort is required to meet volume constraints. *Countermeasures* is an issue for systems which require innovative design in order to be responsive to severe countermeasures, discrimination, or evolving countermeasure threat. The *heritage* issue is a measure of the existence of similar existing designs or technology that may be leveraged upon to simplify the design tasks of this system. These design complexity issues are quantified by use of a subjective scheme.

Several programmatic complexity issues were identified that were believed would further explain variation in the data. The number of *platforms* for which the system is being designed was considered a programmatic issue. It was believed to be more programmatic than technical because additional design costs are realized through further coordination imposed upon the designers, such as technical interchange meetings, etc. The number of government *agencies* is a measure of the number of customers to which the design contractor must report, or the number of services for which design issues must be addressed. The number of *subcontractors* is an issue because an increased number of subcontractors increases the design effort and interfaces may become more challenging and, once again, increase coordination activities. These programmatic complexity issues are quantified by use of counting the occurrences of these characteristics.

This hypothesis was applied to our database of monthly systems. The issues were quantified as depicted in Figure 4-1. For the sake of simplicity, the technical issue values were limited to +/- 0.10. It is believed that since the nominal value for these are 1.0, future researchers or users may wish to add further adjustments. For that reason, a category of adjustment called "additional adjustments" is shown in Figure 4-1. For this example, the technical issues were applied at the subsystem level and were weighted by their respective subsystem hardware costs.

Table 4-1 presents the peak equation that was computed for this hypothesis. Equation 1 utilized all the data points. It represents a dramatic improvement over Equation 5 in Table 3-1 which was also for all 15 data points. Removing the one outlier in Equation 2 gave the best fit statistics of any peak equation. Removing an additional outlier (Equation 3) gave a little less fit than Equation 2 but a lower standard error. Equation 3 is directly comparable to Equation 7 from Table 3-1 as shown in Figure 4-2. Note that the F value has increased, indicating that introduction of the Adjustment variable increases the regression's significance. The r^2 is improved but the standard error has not improved. The residuals were somewhat better, exhibiting a lower average error. The Table 3-1 equation predicted eight points within 20% while this new equation predicted ten points within 20%. Note the exponent on the Adjustment's variable in Equation 3 is lower than that of Equations 1 and 2. This difference is due to the influence of one particular data point that was discarded as an outlier which had the highest adjustment value in the data set. The large exponent makes all of these equations very sensitive to the value of Adjustments and since this is mostly a subjective value, the user is cautioned when using any of these three equations. For this reason, Equation 3 is suggested as the most conservative with respect to the Adjustments variable. Note also that the values used in this regression ranged from 0.92 to 1.13 and that the application of values considerably beyond this range may provided extreme results. If the reader chooses to apply this equation to an estimating problem, the subjective assessments must be sensibly and defensibly applied.

$R_{max} = f$ (PCFU, D1, D2, Adjustment)

Adjustments = subjective complexity variable where 1.0 is the typical norm

Adjustments = technical complexity * program complexity
(weighted by subsystem T_1 if desired)

Technical complexity = 1 +

+ 0.10	Challenging design
- 0.10	Extremely simple design
+ 0.10	Packaging considerations (i.e., small area)
+ 0.10	High countermeasure threat
- 0.10	Good heritage
± n	Additional complexity adjustments as user deems appropriate

Program complexity = 1 +

+ (.02 * X_1)	where X_1 is the number of platforms beyond 1 on which weapon will operate.
+ (.02 * X_2)	where X_2 is the number of government agencies running the program beyond 1.
+ (.01 * X_3)	where X_3 is the number of major subcontractors.
± n	additional programmatic adjustments as user deems appropriate.

Figure 4-1
Adjustment Issue Quantification

Table 4-1

Equations with Adjustments Evaluated

#	EQUATION	r^2	SE	n	F	COMMENTS
1	$0.6030PCFU^{0.3411}ADJ^{5.2693}2.2844^{D1}0.5902^{D2}$	85	0.65	15	21	All data points.
2	$0.7341PCFU^{0.3852}ADJ^{5.0475}1.9222^{D1}0.5141^{D2}$	97	0.48	14	91	Equation #1 less ERINT.
3	$0.7458PCFU^{0.4030}ADJ^{4.2307}1.8971^{D1}0.5353^{D2}$	95	0.41	13	58	Equation #2 less AMRAAM.

Without Adjustments: $Peak = 0.7935\ (Proto\_CFU)^{0.5185}\ 1.9831^{D1}\ 0.6906^{D2}$

With Adjustments: $Peak = 0.7458\ (Proto\_CFU)^{0.4030}\ (ADJ)^{4.2307}\ 1.8971^{D1}\ 0.5353^{D2}$

Where: D1, D2 = 0,0 Dem Val

1,0 EMD

0,1 PIP

	Without	With
r^2	90.89	95.00
F	40.92	58.03
SE	0.4012	0.2272
n	13	13
df	9	9

Figure 4-2

Peak Equation Comparison

5
CONCLUSION

5.1 RESULTS

A primary methodology for estimating Air Vehicle Development Engineering was developed. This method utilizes schedule milestones and the cost of the first prototype. It is applicable to D&V, EMD, or PIP programs. This method is very versatile as discussed in Section 4. The schedule terms and the peak terms are independent so that user-supplied alternatives may be substituted for either if desired. Also, parameters to address subjective issues such as design complexity, heritage, and programmatics were analyzed. It is recommended that Development Engineering cost of other types of systems and equipment be addressed with this type of method. Also the use of milestones could be investigated for applicability to CERs for all other R&D cost accounts.